Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE MEASUREMENT OF PHYSICS INFORMATION

J. CROSBY CHAPMAN
Western Reserve University, Cleveland, Ohio

The degree of care which has been wisely given to the accurate construction and standardization of scales for the measurement of skill and allied factors cannot profitably be employed when constructing measures, which, having a narrower range of application, gauge primarily the amount of information possessed. Such measures are, however, indispensable and must be forthcoming in large numbers if the total work of the schools is to be checked up quantitatively.

The objectives of the study of a science are manifold, ranging from an appreciation of generalized scientific method to the acquirement of the elementary facts. Especially in the initial study of a science the facts and the terminology have to be mastered, for they form the basis upon which further generalization and application rest. While instruction is very incomplete unless the pupil passes beyond the mere phenomena, yet as one essential aim, particularly in the elementary stage, it is necessary to work for a knowledge of the facts of the science. Whether the facts are taught as isolated pieces of information or acquired in the solution of laboratory problems the situation remains that no superstructure can be built until there is a recognized body of information which can be assumed to be the possession of the pupil. From another standpoint—that of detailed rather than general diagnosis—it is clear that the amount of information acquired as the result of instruction will need direct as well as indirect measurement. While the indirect method will seek to determine the extent to which the pupil can use the information acquired and will gauge his knowledge by success in the final application, we must not overlook the fact that two pupils, neither of whom can solve the problems involved in the indirect measurement, are in a very different state if one knows the isolated facts but fails to apply them, while the other has failed to secure the contributory information.

The object of this paper is to call attention to a method which has probably a wide range of usefulness as a measure of informational achievements. This method has the following merits: (1) it can be used in almost any subject in the curriculum; (2) it is objective; (3) it requires no special material for each pupil except paper and pencil. This last advantage deserves attention; the writer has been much struck with the desirability of constructing in more of the common school subjects devices for measurement which do not require the teacher to procure blanks. When experimenting I have found that teachers are willing and even eager to try out objective tests on their classes when there is no necessity for the procurement of blanks, but when such are indispensable, the expense and effort required seem to exceed the critical point of inertia. The hope of the objective movement in education is to be realized by each teacher using the tests as an aid to instruction, not solely by their application on a large scale, usually under compulsion, by the controlling authorities.

CONSTRUCTION OF THE TEST

The measurement here described is the outcome of several meetings with a club comprising the physics teachers in the public schools of Cleveland. In a previous issue of the *School Review*, January, 1918, the author, with two others, presented the results of a study of the achievement of pupils in elementary mechanics. The interest aroused by this study caused a request for a similar measurement which would cover the descriptive parts of those portions of physics dealt with in the common school textbooks under electricity and magnetism, light and sound. Instead of constructing the test myself for the purpose of stimulating interest and giving facility in the application of the method, I met with the group on several occasions to explain the general principle of procedure. It was pointed out that each question must fulfil the following requirements—

1. It must apply specifically to the field of knowledge for which the test is constructed.
2. It must be taken from an essential part of the subject which is contributory to understanding or summarizing a general theory or principle. The question, in other words, should be such that a correct answer would indicate that a distinct meaning had been grasped.
3. It must be so worded as not to be ambiguous.
4. It must be so framed that it can be answered very concisely usually in a single word, or at most a short phrase.
5. It must be such that the short answer given in the test includes all possible correct answers.

The above requirements, particularly four and five, which are a necessity for objective measurement, limit the possible questions. It may often happen that a good question has to be omitted for the simple reason that the number of correct answers makes objective marking impossible. A little practice, however, gives considerable facility in the construction of questions which conform to the above requirements and yet reveal the presence or absence of necessary information and understanding. As a result of these meetings several hundred questions were submitted. A selection was made and combined with ten other questions added by the author after reference to several school texts. These facts are mentioned in order to prove that the rough norms of achievements were not vitiated by any possibility of coaching for the examination—the number of questions submitted and the secrecy of the final selection prevented this factor from affecting the results.

TEST IN PHYSICS—ELECTRICITY AND MAGNETISM, SOUND AND LIGHT

The directions for administering the test and the test itself with the correct answers are given below—

Directions for Administering Test

1. Explain the general nature of the test. Tell the pupils not to take down the question but merely to answer it in a single word or phrase.

2. Dictate each question deliberately twice, and twice only, passing on, after adequate time for writing the answer, to the next problem.

3. Before collecting the papers read the whole set of questions once again.

4. Mark the papers by scoring one point for each answer which covers the essential point given.

PHYSICS TEST IN ELECTRICITY AND MAGNETISM, SOUND AND LIGHT

1. What is the common name applied to the deviation from the true north and south line of a compass needle free to swing in a horizontal plane?

2. What are all the molecules of iron or steel according to the common theory that accounts for magnetism?

3. What kind of positive and negative static electricity is formed on a conductor in the neighborhood of a charge?

4. What is the smallest known electrical charge?

5. What is the quantity of electricity called which passes when one ampere flows for one second?

6. Given the electromotive force and resistance in a circuit, what formula would you use to calculate the current?

7. What is the unit of resistance called?

8. How many conductors are there in the simplest form of condenser?

9. What is the common name of the rotating part of a dynamo, consisting of the coil and its core?

10. How should two cells be connected in order to decrease the internal resistance?

11. What is the common device called which converts the energy of electrical currents into mechanical energy?

12. In what condition is a cell when a film of hydrogen has gathered on the positive plate?

13. What property of a voltmeter prevents it from short circuiting the two lines when connected across?

14. In what form is the energy stored in a storage battery?

15. What instrument is used to pass from a high voltage to a low voltage?

16. What is the chief factor which controls the quality of a tone?

17. With what factor does the frequency of a vibrating string vary directly as the square root?

18. What is the common name applied to the condition of the air in that portion of the wave in which the particles are moving backward?

19. What are caused by a very slight difference in the frequencies of two notes?

20. How many vibrations are there in middle C, international pitch?

21. Give the formula for velocity of sound in terms of wave length and number of vibrations per second.

22. Upon what important phenomenon in light is the conclusion based that light waves are transverse?

23. Through what is white light most commonly passed to produce a continuous spectrum?

24. What do we call the ratio which expresses the speed of light in air divided by its speed in any other medium?

25. What is the common name of instruments used to compare the intensities of two lights?

26. What happens when two waves of light of the same wave length and intensity meet each other in exactly opposite phase?

27. What has been assumed to exist in order to explain the transmission of light from the sun to the earth?

28. If the intensity of light, at a certain distance from a source of light is x, what is the intensity at three times that distance from the source?

29. What is the name of the theory that states that light consists of small particles traveling with enormous velocities?

30. If the object is nearer to the lens than the focal distance, what is the general name applied to the erect and enlarged image produced?

ANSWERS

1. Declination
2. Magnets (small magnets)
3. Induced
4. Electron
5. Coulomb
6. $\frac{E}{R}$ $\left(\frac{\textit{electromotive force}}{\text{resistance}}\right)$
7. Ohm
8. Two
9. Armature
10. Parallel (multiple)
11. Motor
12. Polarized
13. Resistance

14. Chemical
15. Transformer
16. Overtones
17. Tension
18. Rarefaction
19. Beats
20. 256
21. nl (number of vibrations × wave length)
22. Polarization
23. Prism
24. Refractive index
25. Photometer
26. Interference (darkness)
27. Ether
28. $\frac{x}{9}$
29. Corpuscular theory
30. Virtual

PRESENTATION OF RESULTS

This test was given to 158 pupils, boys and girls, of the academic high schools, who were just completing the study of this section of physics; that is, the ground had been covered within the present semester ending June, 1919. The results are presented in three tables showing (1) the percentage of pupils getting each question correct; (2) the distribution of scores in the various sections in the schools; (3) the standard scores worked out on the percentile basis.

TABLE I

Question	Percentage Correct	Relative Difficulty	Question	Percentage Correct	Relative Difficulty
1.........	42	3.2	16........	62	2.7
2.........	65	2.7	17........	55	2.9
3.........	31	3.5	18........	41	3.2
4.........	50	3.0	19........	58	2.8
5.........	45	3.1	20........	74	2.4
6.........	92	1.6	21........	72	2.4
7.........	95	1.4	22........	23	3.7
8.........	61	2.7	23........	60	2.7
9.........	70	2.5	24........	44	3.2
10.........	76	2.3	25........	65	2.6
11.........	50	3.0	26........	34	3.4
12.........	49	3.0	27........	63	2.7
13.........	44	3.2	28........	48	3.1
14.........	43	3.2	29........	29	3.4
15.........	59	2.8	30........	59	2.8

In Table I the percentage of pupils getting each question correct is shown. In addition, the relative difficulty of each question is recorded on the assumption that a question answered by all the pupils falls at -3.0σ and is of "zero difficulty." If these relative degrees of difficulty are used in computing scores, it cannot be too clearly pointed out that the zero used

TABLE II

Total Score	School A			School B			School C		All Sections
	Section *a*	Section *b*	Section *c*	Section *a*	Section *b*	Section *c*	Section *a*	Section *b*	
5	1	.....	1	.....	.....	.....	.....	.....	2
6	1	.....	1	.....	1	.....	1	1	5
7	.....	.....	.....	.....	.....	.....	.....	2	2
8	.....	.....	.....	1	.....	1	1	.....	3
9	.....	.....	.....	.....	.....	1	.....	1	2
10	.....	.....	.....	.....	.....	1	2	1	4
11	.....	.....	1	1	.....	.....	1	.....	3
12	.....	2	.....	3	1	1	1	1	9
13	.....	.....	.....	2	1	.....	.....	.....	3
14	2	.....	1	2	2	.....	2	2	11
15	2	.....	2	1	2	2	2	2	13
16	1	1	1	3	2	2	2	1	13
17	.....	3	.....	3	2	2	1	.....	11
18	.....	1	1	2	2	2	.....	2	10
19	.....	1	6	1	1	2	1	.....	12
20	3	2	2	2	.....	.....	.....	.....	9
21	2	5	4	1	1	.....	1	.....	14
22	1	3	3	1	1	.....	.....	.....	9
23	2	2	.....	.....	.....	1	1	.....	6
24	.....	2	1	.....	.....	.....	1	.....	4
25	3	2	1	.....	2	.....	.....	.....	8
26	1	.....	.....	.....	.....	1	.....	.....	2
27	.....	.....	2	.....	.....	.....	.....	.....	2
28	1	.....	.....	.....	.....	.....	.....	.....	1
29	.....	.....	.....	.....	.....	.....	.....	.....	....
30	.....	.....	.....	.....	.....	.....	.....	.....	....
Median	21.0	21.4	19.9	16.5	17.0	17.0	15.5	14.3	17.8
No. of cases	20	24	27	23	18	16	17	13	158

is, of course, not an absolute zero, whatever hypothetical power that may designate, but merely what may be called a "zero of non-differentiation" for this group.

In Table II, on the basis of number of correct answers, assuming each question of equal difficulty, the distribution of total scores by section and by school is recorded. Considering the small number of pupils on which the test has been tried, it is hardly worth while to weight the question according to the relative degrees of difficulty.

Table III, gives the tentative norms of performance in percentiles based on the 158 cases in one school system.

TABLE III

Percentile	Score
Lowest	5.0
10	10.5
20	13.5
30	15.3
40	16.5
50	17.8
60	19.3
70	20.8
80	22.0
90	24.3
Highest	28.0

WHAT DOES THIS TYPE OF TEST MEASURE?

What significant factors in the knowledge of physics does a test of this kind measure? This a question which it is impossible to answer until the aims of instruction in physics are more clearly defined. Conceivably under present conditions a low correlation with teachers' marks might be a positive recommendation. It was hoped that a comparison of the achievements in this test with the teachers' ratings of the pupils would at least indicate the extent to which the scores in the test corresponded with that unknown product commonly called "physics ability" in the school. Any detailed comparison, however, has been impossible for the following reasons: (1) the unreliability of teachers' marks; (2) the small differentiation between the semester grades. With the first factor many studies make us familiar; the second factor has not been stressed in spite of its obvious effect on incentives and selection of pupils. For example it is not uncommon for 60 to 80 per cent of the pupils to be graded by a teacher within a range of five points, usually 70–75. It cannot be supposed that this small differentiation is a measurement of the true range of ability of such a large percentage; it rather bears witness to the absence of an adequate knowledge of the pupils' abilities on the part of the teacher assigning a grade. Under this condition physics teachers, to whom numbers mean something, naturally adopt a "playing safe" policy.

On the basis of the report on the semester's grade, the three highest and the three lowest from each section have been taken to form two groups—the best and the worst. The corresponding scores of the two groups were 21.3 and 11.7. This furnishes very meager evidence as to the suitability of this type of test, but the author, from a large amount of evidence obtained when engaged in army work, is convinced that tests of this kind are well worth trial when employed for the limited purpose for which they are designed.

It is with pleasure that I acknowledge my indebtedness to the physics teachers of Cleveland including also Mr. C. W. Sutton and Mr. J. B. Welles of the Division of Reference and Research.